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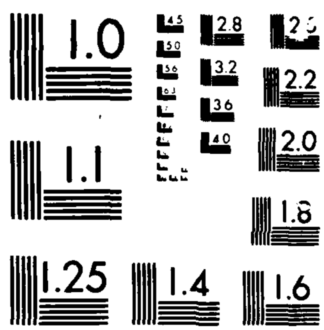

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IDA MEMORANDUM REPORT M-156

A BRIEF ASSESSMENT OF STRUCTURAL COMPOSITE MATERIALS RESEARCH IN UNIVERSITIES IN THE UNITED STATES

R. L. Kerber, *IDA Consultant*

December 1985

Prepared for

Defense Advanced Research Projects Agency

IDA

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, VA 22311

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The use of advanced composite structural materials in defense systems is rapidly increasing and it is expected that this trend will continue in the foreseeable future. Thus, it is important to assess the role of universities to support the technology base and provide appropriate manpower to the defense industry. The results of such a survey and assessment are presented. It is recommended that DARPA support about 5-8 new university-operated composite material activities which should have a strong interaction with industry. Suggested funding needs and technical initiatives are outlined.

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PREFACE

The Institute for Defense Analyses (IDA) was requested by the Defense Advanced Research Projects Agency (DARPA), in its Task Assignment A-97 to make a brief assessment of the status of structural composites research in universities in the United States. This assessment is intended to aid the Materials Science Division of DARPA in its research and development planning.

I. Introduction

The Department of Defense has a constant need to build lighter weight, stiffer, stronger structures with longer lasting materials in sometimes harsh environments. This need has lead to the increased use of engineering materials designed to fit specialized needs. Most of these designed materials are in the form of composites. The growth of technology-based funding for composites over the last fifteen years is shown in Figure 1.

Although this growth rate has been high, the actual use of composites in the field is occurring at a much slower rate. This is due, in part, to conservatism, the lack of engineering experience with these new materials, cost, the inability to perform in-field repairs and, finally, the lack of familiarity of design engineers to the properties of many composites. Many of these problems are being overcome, and interest by systems designers in composites is rapidly increasing. As a result, it is easy to conclude that the use of composite materials in aircraft, tanks, trucks, portable structures, engines, etc., will increase at a rapid rate. This increase will generate a much greater pressure on the scientific community to support this area with a technology base. Currently, approximately 1/3 of all DOD technology base funding in materials and structures is in composites, and this has been the case for the past five years (see Figure 2). A breakdown of these expenditures into specific material areas is given in Figure 3. Also, additional trained material scientists and engineers will be required to support this growth.

With this increased interest in composite materials, it then is important to assess the role and potential of universities in the United States to support, in part, the technology base and to provide appropriate manpower to the defense industry.

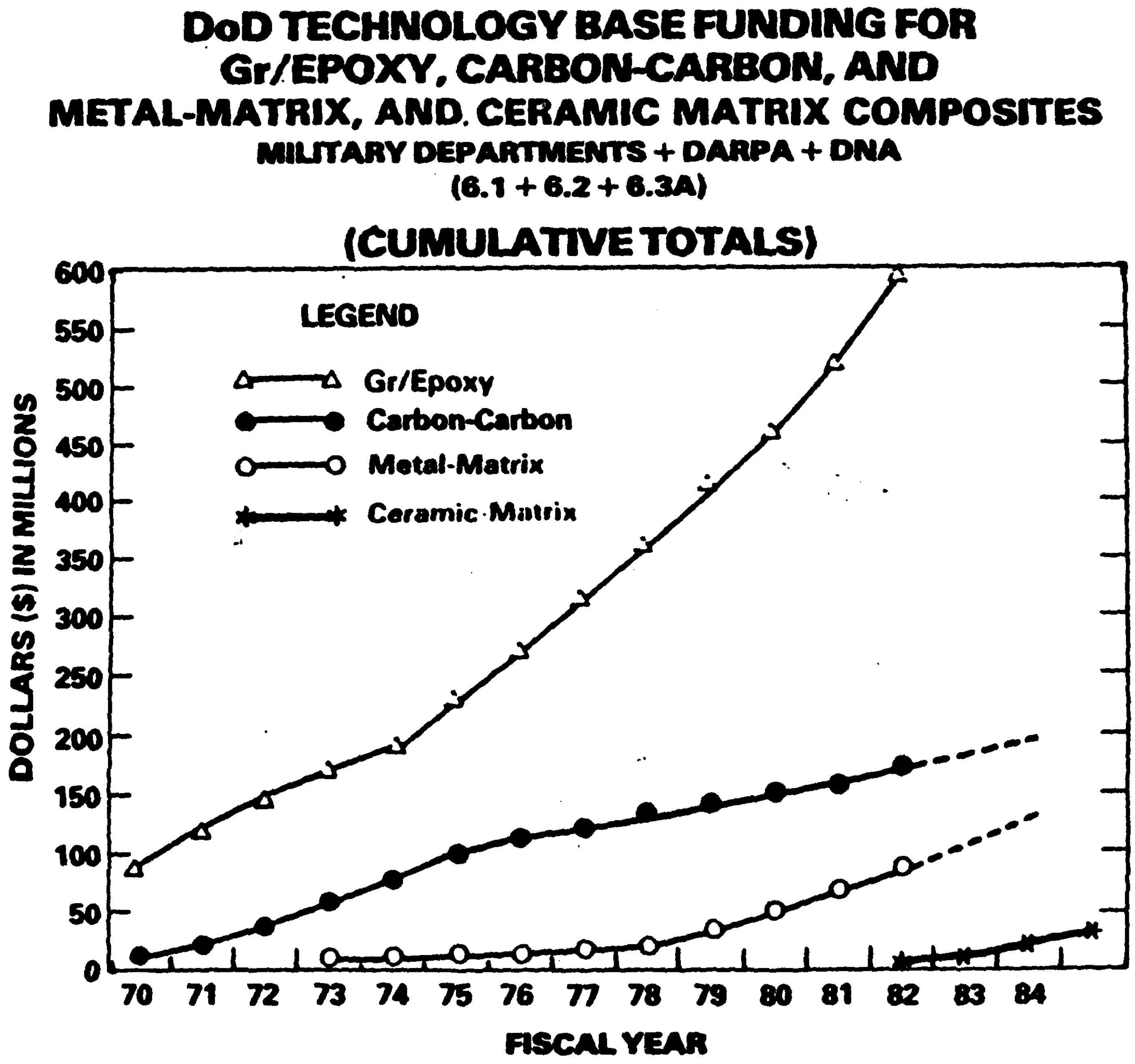

Figure 1. J. Persh, OUSDRE, private communication.

MATERIALS AND STRUCTURES TECHNOLOGY BASE FUNDING TRENDS

ARMY + NAVY + AIR FORCE + DARPA
(6.1 + 6.2 + 6.3A)

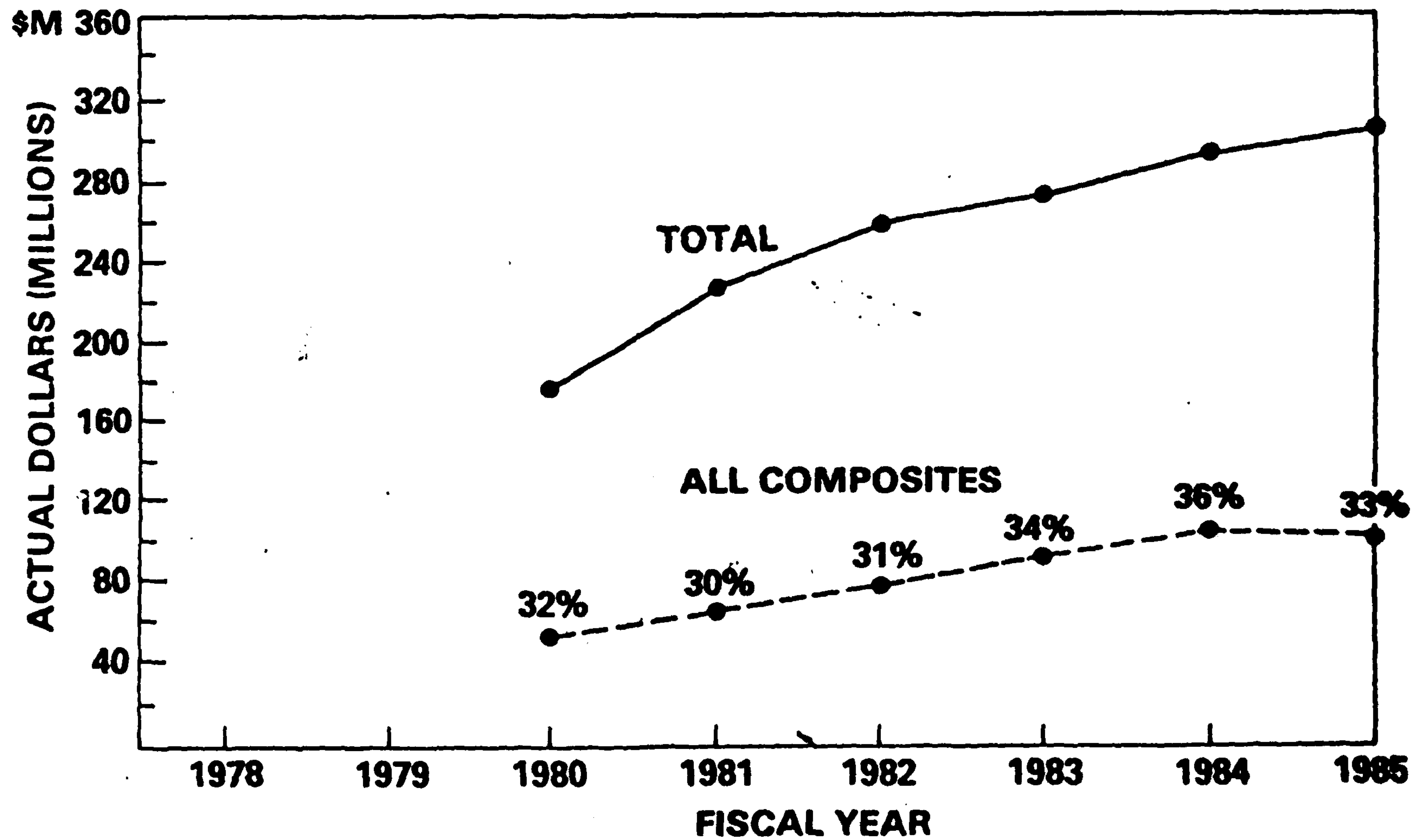

Figure 2. J. Persh, OUSDRE, private communication.

DOD SCIENCE AND TECHNOLOGY

PROGRAMS IN COMPOSITE MATERIALS AND STRUCTURES FUNDING (6.1 + 6.2 + 6.3A) (ALL MISSION AREAS)

COMPOSITE	SERVICE	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
ORGANIC MATRIX COMPOSITES	ARMY	7.0	9.2	10.4	22.9	25.0	23.5	22.9
	NAVY	9.1	9.7	11.0	11.9	10.4	7.0	7.2
	AIR FORCE	9.1	9.6	12.6	14.0	20.5	29.7	25.8
	TOTAL	23.2	20.5	34.0	48.8	55.9	60.2	55.9
CARBON/ CARBON COMPOSITES	ARMY	—	—	—	1.0	1.0	1.0	1.2
	NAVY	3.8	3.8	5.1	4.6	4.2	3.7	3.4
	AIR FORCE	2.3	7.3	8.2	5.2	4.5	4.7	6.9
	DARPA	—	—	—	—	0.8	1.3	2.3
	TOTAL	6.1	11.1	13.3	9.8	10.5	10.7	10.8
METAL MATRIX COMPOSITES	ARMY	3.2	3.2	5.0	4.2	5.4	4.5	4.1
	NAVY	3.8	5.7	8.6	7.5	6.8	6.9	8.3
	AIR FORCE	5.1	6.2	5.3	5.5	5.6	10.0	9.7
	DARPA	0.8	0.8	0.8	2.0	2.0	1.7	2.2
	TOTAL	12.9	13.9	19.7	19.2	19.8	23.1	24.3
CERAMIC MATRIX COMPOSITES	ARMY	—	—	—	—	—	0.2	0.4
	NAVY	1.3	1.6	1.8	1.8	2.0	2.4	2.9
	AIR FORCE	0.1	0.1	0.2	0.2	0.3	0.5	0.6
	DARPA	—	—	—	—	3.6	6.2	5.6
	TOTAL	1.4	1.7	2.0	2.0	5.9	9.3	9.5
	OVERALL TOTALS	43.6	55.2	69.0	79.8	92.1	103.3	100.5

Figure 3. J. Persh, OUSDRE, private communication.

As a result, this study was initiated to achieve the following goals.

1. Examine the status of composites research in U. S. universities.
2. Determine industrial R&D needs relative to universities through
    a. Examination of the need for a stronger technology base.
    b. Examination of the need for more trained people.
3. Assess the opportunities for government support of composites research in universities.
4. Act as a focal point and information source for the DARPA Materials Research Council Meeting discussion on this topic.

The mechanism used to achieve these goals was to collect results of recent studies that were appropriate and to interview a sample of people throughout the country that were representative of industrial composite material users and suppliers, university researchers and government representatives in the composites area. The results of this study are presented in the next sections.

II. Results and Discussion

Two earlier studies on the technology status for polymer composites [1,2] have indicated a significant need for basic research in advanced polymer composites. One study [1], recommends that the government establish approximately three centers in the high-performance polymer composite area. One such center has been established at the University of Delaware and Rutgers through the NSF Engineering Research Center Program. The work at Rutgers is on ceramic matrix composites. A second center in metal-matrix and ceramic matrix composites has been established at Massachusetts Institute of Technology through the Office of Naval Research with funds from the Strategic Defense Initiative. The results of this study will indicate that additional areas of strength are needed, especially in the area of carbon/carbon and ceramic composites.

A. Industrial Input

Input was sought from industrial researchers and research managers to determine their needs with respect to a technology base in the composites area and the need for trained research personnel to support composites research and development. The major industries important in the composite materials area include aircraft, aerospace, chemical, electronics, automotive, material suppliers and manufacturers, and government laboratories.

Those individuals from industry that were contacted are listed in Table I. Some general conclusions were drawn from this group; those conclusions are listed below.

1. There is a strong need for research in processing technology. Currently, there is very little science base for processing. New processing methods, sensors and nondestructive evaluation techniques to monitor processing and to control the processes in real time to improve quality and performance are needed.
2. University research is very weak in carbon/carbon, high temperature resin composites, ceramic composites, and, to a lesser extent, there is a weakness in metal matrix composites. University research is also very weak in process technology.
3. University research is strong in polymer/organic and graphite/epoxy composite materials.
4. University research is relatively strong in mechanics, characterization, surface science and modelling.
5. Currently, universities fall short in giving students state of the art technology.
6. Composites research needs "new blood" and "fresh ideas". There is little need for generalists in the composites area, but attempts should be made to bring strong researchers from other science disciplines together to look at interdisciplinary problems.
7. There is a strong need for research in the integration of the design, fabrication process, and post process testing and characterization to reflect a specific end use. Such a concept would incorporate Computer Aided Design (CAD), Computer Aided Manufacture (CAM), and artificial intelligence (AI) in the design and process methodology.
8. Currently, there is too much part replacement with composites in contrast to the opportunity of replacing function with fewer (integrated) parts.
9. Government funding of universities should require industry participation to provide a focus and relevance to the basic research. Some interaction with government laboratories should also be required.

TABLE I

INDUSTRIAL COMPOSITE MATERIAL CONTACTS

Peter Zavitsanos	General Electric
Robert Washburn	Accurex
Herbert Volk	Vought
Arthur Taverna	AVCO
Ernie Petrick	General Dynamics
Carl Prewo	United Technologies
Roger Pepper	FMI
Robert Shaffer	Hitco
Bill Atwell	Dow Corning
Carl Johnson	Ford Motor Company
Mohan Misra	Martin Marietta
Dale Wetzel	Chrysler
Mike Buckley	Rockwell Science Center
Roger Bacon	Union Carbide
David Schmueser	General Motors
Bohdan Lisowsky	Eaton Corporation
Thomas Regulski	Dow Chemical
James Whittier	Aerospace Corporation

10. Involvement of foreign nationals at universities may pose problems in areas of controlled technology. The Department of Defense should examine this issue very carefully so that they do not exclude universities from working on basic research in critical technology areas.

There were additional specific suggestions from the industrial group. Those are listed here.

1. Universities should be equipped to develop and maintain unique and specialized analytical capabilities and techniques that characterize materials in bulk surfaces and interfaces, and perform nondestructive evaluation.
2. There are needs for research in:
   a. fiber coatings
   b. material stability
   c. environmental effects
   d. fracture, failure and fatigue
   e. life prediction
   f. attachment and fastening
   g. sensor development for process control
   h. chemical characterization and basic chemical processing
   i. process development to reduce cost and fabrication time

Although each company may identify a few nationally or internationally known university professors either for sponsored research or consulting, most relied most heavily on those institutions nearest to them to provide support to their internal or externally sponsored research and development.

In conclusion, there was an indication by the industrial community of a strong need for increased basic research and trained people from universities provided that the general conclusions mentioned above were kept in mind. The single most important observation from this group was that progress is now limited by our fundamental knowledge.

B. <u>Government Input</u>

Some individuals in government agencies were contacted that support or perform basic research in composite materials to determine their assessment of the need for additional funding of composites materials research and to get their perceptions of the currently active research efforts in universities. Those people contacted are listed in Table II.

TABLE II

GOVERNMENT CONTACTS

Office of Naval Research	S. Fishman
Army Research Office	G. Mayer
Wright Aeronautical Laboratories	L. Drzal
	C. Lee
National Science Foundation	R. Reynik
	N. Bikalas

Very strong need was identified from all government people for the increased support for university research to provide basic technology and trained personnel. This observation was based on the increased role of composite materials in many Department of Defense applications, the increased capability and activity in Europe, Japan and the Soviet Union in composite materials research, development and production, and some very fundamental holes in our current technology base in advanced composite materials.

The specific needs indicated by this group included the following.

1. Processing science is needed to support the fabrication and production of most composites.
2. Improved techniques are strongly needed in nondestructive evaluation (NDE).
3. Combination of NDE, pattern recognition, artificial intelligence are strongly needed to improve material quality, reliability, and to eliminate batch-to-batch variations.
4. The materials areas where much stronger research is needed included carbon/carbon, ceramic matrix, metal matrix, and advanced organic/polymer matrix composites.
5. Research that includes fiber and interface science is needed.
6. Specialized research facilities and centers of strength should be developed in all areas.
7. Mechanics research that includes the microstructure effects of heterogeneous composites is needed.
8. Mechanics associated with dynamical loading is not well known.
9. Formal mechanisms to insure technology transfer from the university to the industry are essential.
10. Research is needed to:
    a. increase strength and strain to failure of carbon fibers.
    b. improve compression properties of resin matrix composites.
    c. increase fracture toughness of resin matrix composites.
    d. develop infield repair capability.
    e. reduced cure time of resin matrix composites.
    f. develop new ideas in bonding, adhesion and attachment.
    g. develop high temperature stability.

h. develop cost-effective processing that can lead to high rate production.

i. improve environmental stability.

It is not surprising that a strong overlap exists between the observations of government and industrial representatives.

C. University Activity

As a result of the input from the industrial and government sources, several universities were identified that had relatively strong research efforts in composite materials. Those universities are listed in Table III. Individuals in all but one of these schools were interviewed on the telephone to determine the nature of the research activity at these institutions. That activity is summarized in Table IV. Other institutions were mentioned that either have some research grant or contract efforts with government or industry or, at least, had a consulting arrangement with industry. Those mentioned are listed in Table V.

It is nearly impossible to develop a comparison of university activity that would not be very controversial. An attempt to do this is given in Table IV. Since most work is interdisciplinary, the activity usually includes characterization and mechanics. Often, universities concentrate on one or two materials but dabble in all. Hence, the areas represented in Table IV tend to overstate the activity of most universities. The funding level is a more accurate representation of activity, although determining a precise level of funding is not easy either. Therefore, Table IV is more an indication of university activity than a quantitative measure.

In general, the universities are quite aware of the opportunities for growth of research activity from both government and industry sources and the need for trained scientists and engineers. As a result, many universities are planning to expand their programs in the composite materials area. Some universities are receiving and others are expecting significant financial support from their state governments for increased university research and education in advanced materials.

As one plans additional support of composite materials in universities by the Department of Defense, the issue of control of critical technologies must be addressed. In general, universities cannot conduct classified research nor can they control access of research

TABLE III
UNIVERSITY CONTACTS

Carnegie-Mellon University

Case Western Reserve University

University of Delaware

Massachusetts Institute of Technology

Michigan State University

Rensselaer Polytechnic Institute

Texas A & M University

University of Texas

Virginia Polytechnic Institute & State University

Washington University (St. Louis)

University of Washington (not contacted)

TABLE IV
UNIVERSITIES CONTACTED

University	Polymers	Ceramics	Metal-Matrix	Carbons	Character-ization	Mech-anics	Interface Science	Process-ing	Environ-mental	Fracture Damage & Fatigue	Friction & Wear	Funding Level
Carnegie-Mellon University			X		X	X		X		X		A
Case Western Reserve University	X	X		X			X	X	X			B
University of Delaware (with Rutgers)	X	X	X	X	X	X	X	X	X	X		C
Massachusetts Institute of Technology	X	X	X	X	X	X	X	X	X	X		C
Michigan State University	X	X		X	X	X	X	X	X	X		B
Rensselaer Polytechnic Institute	X	X		X	X	X	X	X	X	X		B
Texas A & M University	X		X			X			X	X		B
University of Texas	X		X		X	X	X	X	X		X	A
University of Utah						X	X			X		A
Virginia Polytechnic Institute & State Univ.	X	X	X	X	X	X			X	X		C
Washington University (St. Louis)	X				X	X		X	X	X		A

A = < \$1M/yr
B = ∿ \$1M/yr
C = >> \$1M/yr

TABLE V
OTHER UNIVERSITIES MENTIONED

University of Akron	University of Illinois, Urbana
Alfred University	University of Maryland
Arizona State University	University of Massachusetts
University of California--at Berkeley	University of Michigan
University of California--at Santa Barbara	Ohio State University
Clemson University	Pennsylvania State University
Colorado School of Mines	Rice University
Colorado State University	Rutgers University
Drexel University	Stanford University
University of Florida	University of Virginia
	University of Wyoming

TABLE VI
DOCTORATE DEGREES IN ENGINEERING

	Foreign Nationals	Doctorate Total	Schools Reporting
1984	1253	3234	140
1983	1192	3023	---
1982	1167	2887	---
1981	1054	2841	---
1980	982	---	---

Source: Engineering Manpower Commission of the American Association of Engineering Societies, Inc.

findings or activities to only U.S. citizens. In Table VI, this problem is highlighted by noting the number of foreign nationals receiving doctorate degrees in engineering from U.S. universities.

In addition, many engineering schools have more foreign nationals currently enrolled in doctorate programs than U.S. citizens.

This problem must be carefully addressed by the Department of Defense to avoid the loss of the support of some of its best and most creative scientists and engineers (i.e., the professors and graduate students in the universities) and to encourage its own citizens to enter critical science and technology fields not only in composite materials or material science, but in general.

III. Possible Funding Mechanisms

The National Science Foundation has funded the Materials Research Laboratories (which were originated at DARPA), the Engineering Research Centers, and used the University-Industry Cooperative to support interdisciplinary activity in targeted research areas. Announcements from the NSF describing the latter two programs as well as the Materials Research Group Program are given in Appendix A.

IV. Recommendations

As a result of this study, the following recommendations are made.

1. It is recommended that DARPA support approximately 5-8 new activities. For lack of a better word, we will call these Composite Material Clusters since the word center or minicenter is gaining some negative connotations in Academia.
2. These clusters would focus about 5-6 individuals identified as key people in targeted technical areas.
3. Each cluster should have a strong interaction with industry involving both financial support and the interchange and interaction of researchers from both the university and the industry partner.
4. Cluster funding should increase to approximately $1M/yr after 1-2 years then decrease to zero after seven years. Government support of the cluster should be viewed as seed funds to develop a critical mass in the target technology. It is expected that at the end of the seeding cycle successful clusters would have

sufficient funding from competitive government grants and contracts and from industry to remain viable on the basis of their performance alone.

5. For each $100K of cluster funding (excluding equipment), the institution would be eligible to receive a $20K fellowship that could be used to support a U.S. citizen to study and conduct research in support of the goals of the cluster.
6. These clusters should concentrate initially on a composite type such as carbon/carbon high temperature composites or ceramics and include as many aspects of research associated with that type as possible. For example, processing, interfacial properties and modification, microstructure, characterization, and mechanical properties are all interrelated, and real progress requires a multidisciplinary approach [3].

V. References

1. "Report of the Research Briefing Panel on High-Performance Polymer Composites" (D. McCall and R. Pariser, co-chairmen), Research Briefings 1984, National Academy Press, Washington, D.C.

2. "Polymer Science and Engineering: Challenges, Needs, and Opportunities," Report from Ad Hoc Panel on Polymer Science and Engineering, Committee on Chemical Sciences, Solid State Sciences Committee, Assembly of Mathematical Sciences and Physical Sciences, National Research Council, 1981.

3. "Composite Centers," A. G. Evans, R. Mehrabian, and J. Williams, DARPA Materials Research Council Recommendation, August, 1985. This is attached as Appendix B.

VI. APPENDICES

NATIONAL SCIENCE FOUNDATION*

Program Announcement
ENGINEERING RESEARCH CENTERS
(Centers for Cross-Disciplinary Research in Engineering)

The Directorate for Engineering will continue the Engineering Research Centers program started in Fiscal Year 1985. The goal of the Centers program is to develop fundamental knowledge in engineering fields that will enhance the international competitiveness of U.S. industry and prepare engineers to contribute through better engineering practice. Engineering education and research are key elements in improving U.S. industrial productivity, and they must be firmly linked in the Centers. The Centers will be supported to meet a need for providing cross-disciplinary research opportunities for faculty and students, for providing fundamental knowledge which can contribute to the solution of important national problems, and for preparing engineering graduates with the diversity and quality of education needed by U.S. industry.

While the Centers will differ from one another, they should all share four defining characteristics: First, they should provide for working relations between students and faculty on the one hand, and practicing engineers and scientists on the other. Second, their programs should emphasize the synthesis of engineering knowledge; they should seek to integrate different disciplines in order to bring together the requisite knowledge, methodologies, and tools to solve issues important to engineering practitioners. Third, the programs must contribute to the increased effectiveness of all levels of engineering education. Fourth, the Centers should have a strong commitment from industry (money, equipment, and people) to assure its involvement in the research and educational aspects of the Centers.

The Centers are to be located at academic research institutions where they are expected to promote strong links between research and education. Cooperation between one or more schools in a region is encouraged where the combined activity will enhance the Center and the engineering education and research activities of the region.

Each Center should focus on a particular area of both industrial and national importance where development of fundamental engineering knowledge will enhance international competitiveness and is a major technological concern. The proposing institution should identify the subject area and focus of its proposed Center, as well as the approach it considers best to address the area in accordance with the interests and capabilities of the campus and affiliated institutions.

The Centers are expected to possess the following features:

- Provide research opportunities to develop fundamental engineering knowledge in areas critical to U.S. competitiveness where team efforts of individuals from various backgrounds, possessing different engineering and scientific skills, will contribute more to the research and goals of the Center than would occur with individual research grants. The nature of the Center's research should be cross-disciplinary.
- Emphasize the systems aspects of engineering to help educate and train students in synthesizing, integrating, and managing engineering systems.
- Provide experimental capabilities not available to individual investigators because of large instrumentation acquisition costs, requirements for a large number of skilled technicians, or other maintenance and operating requirements.
- Include in the Center the participation of engineers and scientists from industrial organizations in order to focus the activities on current and projected industry needs and enhance the education of students in the systems aspects of engineering. State and local agencies or government laboratories involved in engineering practice may also be participants.
- Include a significant education component involving both undergraduate and graduate students in the Center research activities, since such participation would expose future engineers to aspects of many engineering fields and better prepare them for the systems nature of engineering practice.
- Develop new methods for the timely and successful transfer of knowledge to industrial users. Codification

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Programs described in this announcement are in Category 47.041 (Engineering Science) of the "Catalog of Federal Domestic Assistance."

*From NSF Manual

National Science Foundation *
Washington, DC 20550

Division of Materials Research
Materials Research Groups Program

INTRODUCTION

This announcement describes the Materials Research Groups (MRG) Program within the Division of Materials Research (DMR), its relationship to other funding modes, and guidelines for submission of proposals.

PROGRAM RATIONALE

The objective of materials research is to gain a deeper understanding of the properties of materials in terms of the microscopic interactions among their fundamental constituents and in terms of composition and structure. There are two aspects to this objective. First, materials research provides essential scientific underpinning for new technological advances. In many instances, a particular technology is limited by the inability to produce materials with needed properties, such as high strength, corrosion resistance, or special electronic characteristics. Second, materials research is also at the forefront of scientific research areas that are yielding major conceptual advances in scientific understanding, such as universal principles of phase transitions, the nature of the amorphous state, and the behavior of materials with submicron dimensions. Many exciting developments in materials research address both of these objectives; e.g., research on the surface of silicon and studies of the environmental causes of cracking. As these examples demonstrate, materials research is a diverse area of research that is not only essential to U.S. technology, but is also at the forefront of fundamental advances in U.S. science.

Progress in materials research demands that certain problems be solved by groups of investigators with diverse backgrounds, who have sophisticated instrumentation at their disposal. Therefore, it has become clear that a new funding mode is needed to recognize the need for such groups and to provide them with adequate support.

PROGRAM DESCRIPTION

The Materials Research Groups (MRG) Program provides support for collaborative, multi-investigator research within the purview of the Division of Materials Research. Such research is expected to address major problems in materials research which require the combined expertise of several investigators and requisite instrumentation.

DMR FUNDING MODES

The new MRG Program complements existing funding modes of the Division of Materials Research:

- *Scientific Research Project Support* (*SRPS*)—supports individual projects from the programs designated Solid State Physics, Solid State Chemistry, Low Temperature Physics, Condensed Matter Theory, Metallurgy, Ceramics and Electronic Materials, and Polymers.
- *Materials Research Laboratories* (*MRL*) *Program*—supports fourteen major university-based research laboratories that carry out interdisciplinary and collaborative materials research.
- *National Facilities* (*NAF*) *Program*—supports the National Magnet Laboratory at the Massachusetts Institute of Technology, the Wisconsin Synchrotron Radiation Center, the Cornell High Energy Synchrotron Source, the National Center for Small-Angle Scattering Research at Oak Ridge National Laboratory, the National Center for High Resolution Electron Microscopy at Arizona State University, and the Center for Research in Surface Science and Submicron Analysis at Montana State University.
- *Instrumentation for Materials Research* (*IMR*) *Program*—supports multi-user, multi-programmatic instrumentation, closed-cycle helium liquefaction systems, development of new instrumentation, and single-investigator instrumentation costing over $200,000.

*From NSF Manual

UNIVERSITY/INDUSTRY COOPERATIVE RESEARCH CENTERS

The University/Industry Cooperative Research Centers Program stimulates industrial support of university research through the establishment of centers that create long term collaboration between the university and industry in research areas of high mutual interest. The program initiates university research programs with cofunding from groups of industrial firms that are compatible with university research objectives and also responsive to industry's research needs. NSF and industry's joint support in initiating a center provide for a broad-based research program that is large enough to be of interest to industry but is too large for any one company to normally undertake alone. Research programs of the centers generally correspond to the university's scientific and engineering areas of expertise and generally have participants that are or have been principal investigators of other NSF research grants. Most centers have an interdisciplinary research program to meet industry's research needs. All centers are to increase the industrial support for their research program as NSF support is phased out within a period of five years. A center is considered a success when its research funding is at its original level or higher and NSF no longer provides supports.

The program awards planning grants to study possible alternatives for both structure and content of the research plan to be pursued, and to evaluate industry's interest in a potential center. Since the program emphasizes local autonomy and separate development, each center develops along its independent path determined by both the principal investigator, the university policy and objectives, and the industry requirement and response. NSF views each center as an experiment and funds an independent evaluation to study the variables of each center's operation to assess its outcome.

Each center that has been started or is in the planning stage has been recommended by and/or coordinated with the NSF program manager handling the scientific discipline involved. Thus, the center augments the scientific research support thrust of NSF programs.

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Robert Mehrabian
Dean, College of Engineering

Santa Barbara, California 93106
(805) 961-3141

August 20, 1985

Dr. Ben Wilcox
Assistant Director
Materials Science Division
DARPA
1400 Wilson Blvd.
Arlington, VA 22209

Dear Ben,

Enclosed is the information on Composite Centers that you requested from Tony Evans. We have put together what we believe to be appropriate suggestions for DARPA.

Sincerely yours,

Robert

Robert Mehrabian
Dean
College of Engineering

cc: J. Williams
M. Sinnott

COMPOSITES CENTERS

A.G. Evans. R. Mehrabian, J. Williams

A survey of research on composite materials, both historically and currently funded in the U.S. (Kerber), has revealed that the principal fundamental research activity has focussed on organic matrix composites. Specifically, the Air Force has provided appreciable research support on such materials and, recently, NSF has established an Engineering Research Center at Deleware that has its major emphasis on this class of composite. More recently, basic research on coarse metal matrix composites has also enjoyed moderately good funding, with the establishment of an SDI funded center, based at M.I.T. By contrast, there has been little research funding, at academic institutions, on other classes of composites of importance to DOD: namely carbon/carbon, ceramic matrix, intermetallic matrix and ultrafine microstructure composites. We endorse DARPA involvement in the funding of research at Universities on these composite systems.

Composites research is necessarily multidisciplinary; it involves aspects of processing science, of characterization (both microstructural and interfacial, especially using electron microscopy techniques, with STEM), of mechanical testing and design and of applied mechanics. For example, significant research progress cannot be achieved by concentrating simply on composite processing, without also understanding the connection between processing/microstructure and mechanical behavior. Similarly, knowledge of mechanical behavior without processing expertise has limited impact on the field. Consequently, it is deemed essential that multidisciplinary group(s) be identified and funded.

Therefore, DARPA funding of a research center based at a single discipline (e.g. processing) is regarded as undesirable. Furthermore few single universities can be expected to acquire the expertise generally needed to address such multidisciplinary problems. Hence, it is proposed that DARPA consider funding both single university centers, at universities with the necessary multi-disciplinary capabilities, and research clusters of several smaller institutions that bring together the necessary multi-disciplinary talents (e.g. 2 at Universities and 1 in an industrial laboratory). Each center or cluster will deal with a specific composite system.

It is further considered that each research center or cluster on composites should not have responsibility for a single aspect of composite research, i.e. just processing or just applied mechanics. Experience dictates that cross-disciplinary communication is severely restricted by such an arrangement of research topics. Instead, each center or cluster should be sufficiently comprehensive to address all aspects of the research that deal with a specific composite type. In this regard, it it noted that typically only processing is specific to a composite material: the characterization, testing and applied mechanics have much commonality amongst materials. Hence, it is recommended that each center or cluster have one (or more) composite type as the central theme, and should contain expertise in the processing of that composite, as well as in characterization, testing and applied mechanics. With this arrangement it appears that three to four centers or clusters funded by DARPA would provide a substantial research base concerned with composites (other than organic and coarse metal matrix materials). To ensure adequate funding and time for the generation of a research base, each center or cluster should have funding of approximately $1M per year for 5 years.

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